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EFFECTIVENESS OF PAINT PRIMERS AND PAINTS IN RETARDING THE ABSORPTION OF MOISTURE BY WOOD

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Coatings of paint and varnish retard the exchange of moisture between wood and its environment, their effectiveness varying widely with the nature of the coating material, the adequacy with which it is applied, and, in the case of coatings exposed to the weather, with its age. In previous publications (5,1,)[3] it was pointed out that the effectiveness of coatings against moisture exchange measures accurately their value as protective coatings and a technic of measuring the effectiveness objectively was described. Such methods of quantitative evaluation of serviceableness, independent of personal judgments by inspectors, should prove especially useful in paint technology, which has long suffered badly from lack of them. Although the dominant considerations in serviceableness of paint coatings are usually maintenance of the integrity and appearance of the coating rather than protection of the wood, protection may prove to bear directly upon maintenance of integrity inasmuch as failure in integrity is occasioned not alone by change in intrinsic properties of the coating itself but also by extrinsic stresses acting on the aged coating, among which may be the movement of the wood in response to changing moisture conditions.

Interest has lately been focused upon the effectiveness of coatings against moisture because of the development of mill-priming and of back-priming (9, 6,). Back-priming has protection against moisture as its only objective. Mill-priming is urged for protection against moisture during shipment and storage and for superior maintenance of protection and coating integrity after erection and application of finishing-coat paints. Because of these new developments study of the effectiveness of coatings against moisture must consider not only completed paint jobs consisting of two or three coats of one kind of paint, but the effectiveness of priming-coats alone and of special priming-paints followed by finishing-coats of ordinary paint. The experiments described in this report furnish data for discussion of these new developments.

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[2] Forest Service, U. S. Department of Agriculture maintained at Madison, Wisconsin in cooperation with the University of Wisconsin.

[3] Numbers in parentheses refer to citations listed at the end of the paper.

Experimental Procedure

Moisture excluding effectiveness was measured by the Forest Products Laboratory method (5, 1) on test specimens of southern yellow pine, Douglas fir, northern white pine, and redwood. The specimens were 5/8 by 4 by 8 inches[4] in size with rounded edges and corners. They consisted entirely of clear heartwood. Coatings were applied to all surfaces of the specimens after the wood had been brought to equilibrium at 60 per cent relative humidity and 80° F. (27° C.). Moisture movement through the coatings was measured by the gain in weight of the specimens after transferring them from 60 per cent humidity to a damp air chamber for one week.

Since the coatings tested range in effectiveness from very high to very low it was necessary to select the wood specimens very carefully and to divide them into sets of closely matched specimens, each set having its own uncoated control specimen to serve as a basis for calculating the effectiveness of the coatings applied to the other specimens of the set. The experiments required 1,344 specimens, divided into 21 sets of 16 matched specimens for each of the four species.

Matching of test specimens was accomplished as follows: The raw material consisted of 1 by 6 inch by 16 foot boards of clear southern yellow pine, 1 by 6 inch by 12 or 14 foot boards of clear Douglas fir, 1 by 12 inch by 16 foot boards of No. 2 common northern white pine, and 2 by 6 inch by 16 foot planks of clear redwood. Each board was selected carefully by visual inspection for uniformity in density, resinousness, and width of growth rings throughout its length. All the southern pine, Douglas fir, and white pine boards were flat grain. The redwood planks were edge grain. Each board was given a reference number and was then cut into test specimens; each specimen was marked with the number and position in the board from which it was cut. The specimens were then placed in a room at 60 per cent relative humidity until they attained constant weight.

Specimens containing knots or other defects were rejected and each of the remaining specimens was weighed. Each species was then divided into 21 sets of 16 specimens each, taking the 16 from one board provided that they were sufficiently uniform in weight. The least uniform set accepted was one of southern pine in which the range in weight of the specimens was 218 to 245 grams, a variation of ± 5.8 per cent from the average. In order to keep the variation in weight

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[4] Metric equivalents of the units of measure reported in this paper are: 1 inch, 2.54 centimeters; 1 foot, 30.48 centimeters; 1 gallon, 3.785 liters; 1 pound, 0.4536 kilograms.

within that limit some sets of specimens were taken from two or even from three different boards but in that case care was taken to see that the boards were very similar in width of growth rings and angle of intersection of the surfaces with the growth rings. Of the 21 sets of specimens for each species, 20 sets of white pine, 11 of redwood, 16 of Douglas fir, and 11 of southern pine came entirely from one board each; the remaining sets came from two boards except 4 sets of southern pine and 1 of redwood, which came from three boards. For the 21 sets of each species the average variation in weight was ± 4.1 per cent for southern yellow pine, ± 3.5 per cent for northern white pine, ± 2.5 per cent for Douglas fir, and ± 1.9 per cent for redwood.

All of the specimens were then transferred to a damp air chamber for one week and the increase in weight determined in order to make sure that the specimens within each set were reasonably uniform in absorption. The specimens were then reconditioned in the 60 per cent humidity room before painting.

The 21 sets of matched specimens of each species were then assigned to 7 series of sets each series consisting of three groups. The series were designated respectively the "100 series", "200 series", etc. up to the "700 series" and the groups within each series were designated respectively the "A group", "B group", and "C group". Since each set contained 16 matched specimens of which one was required for the unpainted control specimen for the set there were 15 specimens in each set available for coating. Of these two were assigned as painted controls by means of which the validity of comparisons between series could be established, leaving 13 specimens in each set available for painting with coatings to be studied. Accordingly the primers and paints to be tested were divided into 7 series of 13 paints each corresponding to the 7 series of sets of specimens.

Of the three groups of sets within each series the "A group" was assigned to the testing of priming coats alone, before and after exposure to the weather. The "B group" was assigned to tests in which the priming-coat paints were covered with two coats of white lead linseed oil paint, tests being made after the application of each coat and then after exposure to the weather for successive intervals of six months. The tests on group B reveal the contribution made by special primers to the effectiveness and maintenance of effectiveness of completed paint jobs in which the finishing coats are the same throughout; it will be shown from the results that this contribution by primers can not be determined from the effectiveness of the primer before it has been covered with a succeeding coat of paint. The "C group" was assigned to tests in which different paints were each applied in three-coat work and tested after each coat and after exposure to the weather for successive intervals of 6 months. Unpainted control specimens, however, were never exposed to the weather but were always held in 60 per cent relative humidity while the painted specimens were on the exposure racks.

During the progress of these experiments the Forest Products Laboratory moved into a new building in which a newly equipped set of rooms of constant temperature and humidity is provided. The new equipment permits closer control of conditions than was possible in the former quarters. In the old damp-air chamber the readings varied from a relative humidity of 95 per cent to a relative humidity of nearly 100 per cent; in the new room it is held at 97 per cent. For conditioning the specimens before subjecting them to damp air and for storage of unpainted controls while the painted specimens are exposed to the weather they were formerly placed in a room at approximately 60 per cent relative humidity; they are now placed in a room held closely at 65 per cent. In these experiments all tests for effectiveness before exposure to the weather and tests of group A after 6 weeks exposure were made in the old equipment.

Calculation of Effectiveness Rating

The degree to which coatings retard the exchange of moisture between wood and its environment is expressed in terms of their effectiveness ratings. The moisture movement through a coated specimen during 7 days in 97 per cent relative humidity expressed as a percentage of the moisture movement through a matched specimen of uncoated wood during the same interval in 97 per cent humidity is taken as the effectiveness rating of the coating. Since the moisture movement through very ineffective coatings, like that into uncoated wood, depends upon the weight of the specimen and the kind of wood while the movement through very effective coatings depends almost entirely upon the surface area of the specimen regardless of its weight or species, comparison of coatings that differ greatly in effectiveness can be made fairly only if the effectiveness of each coating has been determined with coated and uncoated specimens of nearly the same weight, species, and dimensions.

The effectiveness ratings recorded in this report are averages of the four ratings determined separately for southern yellow pine, Douglas fir, northern white pine, and redwood.

Second- and Third-Coat Paints for Group B

All painted specimens of group B, except certain of series 600 to be described later, received the same second- and third-coat paints, the composition of which is recorded in Table 1.

Table 1. -- Second- and third-coat paints for specimens of group B.

Composition	Second-coat	Third-coat
Basic carbonate white lead (87 lbs.), gallons	1.53	1.53
Raw linseed oil, gallons	2.18	3.93
Turpentine, gallons	1.50	.125
Paint drier, gallons	.125	.125
Pigment volume, per cent	41.3	28.0

Paints for Painted Control Specimens

In order to provide a basis for comparing coatings tested in different series and to indicate the degree of reproducibility of the results, one specimen of each set throughout the 7 series was painted with white lead linseed oil paint and a second specimen with a white lead paint made with a Bakelite paint oil (Bakelite Corporation formula XV-2196). The composition of these paints is recorded in Table 2.

Table 2. -- White lead paints for painted control specimens.

Composition	Primer (Group A, B, C)	Second-coat (Group C)	Third-coat (Group C)
Linseed oil paint, X02			
Basic carbonate white lead (87 lbs.), gallons	1.53	1.53	1.53
Raw linseed oil, gallons	4.68	2.42	3.93
Turpentine, gallons	1.75	1.30	.125
Paint drier, gallons	.125	.125	.125
Pigment volume, per cent	24.60	38.30	28.00
Bakelite oil paint, X03			
Basic carbonate white lead (87 lbs.), gallons	1.53	1.53	1.53
Non-volatile in paint oil, gals.	4.68	2.18	3.93
Mineral spirits, gallons	.68	.32	.59
Turpentine, gallons	1.00	1.18	----
Paint drier, gallons	.15	.15	.15
Pigment volume, per cent	24.60	41.30	28.00

The 100 Series -- Aluminum Paints

Paints were made with two forms of aluminum powder: dry, polished powder of the degree of fineness designated "standard varnish grade", and commercial paste aluminum powder. The paste consisted of 60 per cent by weight aluminum and 40 per cent mineral spirits; the powder was of finer particle size than standard varnish grade. Each of the following paints was applied as primer on specimens of groups A, B, and C of the 100 series, and as second- and third-coat paints on specimens of group C.

No. 104 -- 2 lbs. of paste aluminum in 1 gal. of varnish A.
No. 105 -- 2 lbs. of paste aluminum in 1 gal. of Bakelite varnish (50-gal. length in oil, 89.5 per cent non-volatile by weight)
No. 106 -- 2 lbs. of dry aluminum in 1 gal. of varnish A.
No. 107 -- 1.07 lbs. of dry aluminum in 1 gal. of varnish A.
No. 108 -- 2 lbs. of dry aluminum in 1 gal. of Bakelite varnish.
No. 109 -- 1.07 lbs. of dry aluminum in 1 gal. of Bakelite varnish.
No. 110 -- 2 lbs. of dry aluminum in 1 gal. of ester gum varnish of 75-gal. length in oil and 49 per cent non-volatile
No. 111 -- 2 lbs. of dry aluminum in 1 gal. of ester gum varnish of 33-gal. length in oil and 49 per cent non-volatile.
No. 112 -- 2 lbs. of dry aluminum in 1 gal. of commercial glycerol-phthalate synthetic drying oil vehicle for aluminum paint.
No. 113 -- 2 lbs. of dry aluminum in 1 gal. of "4-lbs. cut" white shellac varnish and 0.04 gal. of castor oil.
No. 114 -- 2 lbs. of dry aluminum, 1 gal. of raw linseed oil, and 0.03 gal. of paint drier.
No. 115 -- 2 lbs. of dry aluminum in 1 gal. of nitrocellulose-rezyl resin wood lacquer.

The 200 Series -- White Linseed Oil Paints

This series, together with the 300 and 400 series, is designed to demonstrate the contribution to effectiveness against moisture movement made by the kind of pigment in linseed oil paint. Paints were made with each of nine opaque white pigments and with 5 different mixtures of white pigments or of white and inert pigments. No white pigment other than white lead, of course, is practicable as the sole pigment in linseed oil house paint, but the behavior of the single-pigment paints is of interest from the point of view of theories of paint formulation.

The proper proportioning of pigments and liquids in making paints for the purpose of comparing different pigments and pigment mixtures is subject to controversy. Until the distribution of particle size of the different pigments and their state of dispersion in mixtures of linseed oil and turpentine are better understood formulation must remain arbitrary. For the present the writer believes that paints for fair comparison should be mixed with constant ratios by volume of total pigment, drying oil, and thinner except for a few colored pigments for which an extra amount of thinner is necessary to make the paint brushable. Accordingly all of the white paints were mixed in the proportions given in Table 2 for white lead linseed oil paint, No. X02. The volumes of the pigments were calculated from the bulking values published by Gardner (7).

The pigments tested in series 200 were:

No. 202 -- Basic carbonate white lead.
No. 204 -- Basic sulfate white lead.
No. 205 -- 35 per cent leaded zinc oxide.
No. 206 -- Mixture of 35 per cent by weight basic sulfate white lead and 65 per cent zinc oxide, lead-free.
No. 207 -- Zinc oxide, lead-free.
No. 208 -- Timonox (antimony oxide).
No. 209 -- Titanium oxide.
No. 210 -- Titanox B (25 per cent titanium oxide, 75 per cent barium sulfate).
No. 211 -- Zinc sulfide.
No. 212 -- Lithopone (28 per cent zinc sulfide, 72 per cent barium sulfate).
No. 213 -- 60 per cent by weight basic carbonate white lead, 30 per cent zinc oxide, lead-free, 10 per cent asbestine.
No. 214 -- 60 per cent by weight titanox B, 30 per cent zinc oxide, lead-free, 10 per cent asbestine.
No. 215 -- 40 per cent by weight lithopone, 45 per cent leaded zinc oxide, 7.5 per cent silica, 7.5 per cent asbestine.
No. 216 -- 21.3 per cent by weight basic carbonate white lead, 24.6 per cent zinc oxide, lead-free, 45.9 per cent barium sulfate (blanc fixe), 8.2 per cent asbestine.

The 300 Series -- Colored Linseed Oil Paints

The colored pigments were tested as single-pigment paints only. Most of them are commercially practicable in that form except that the more expensive ones would then make paint cost too much. The proportions by volume of pigments, linseed oil, and turpentine were the same as in

series 200 and in white lead paint No. X02 except that, in the cases stated, extra amounts of turpentine in addition to those given in Table 2 were added to make brushable paints.

No. 304 -- Iron oxide red, (99 per cent ferric oxide)
2d.-coat mixed with 0.86 gal. and 3d.-coat with 1.64 gal. extra turpentine.

No. 305 -- Spanish oxide, (35 per cent ferric oxide, balance silicates).

No. 306 -- Venetian red, (40 per cent ferric oxide, balance calcium sulfate)

No. 307 -- Venetian red, (9 per cent ferric oxide, 12 per cent calcium sulfate, 79 per cent calcium carbonate).

No. 308 -- Yellow oxide, (92 per cent ferric oxide monohydrate, 6 per cent calcium sulfate, 1 per cent silica and alumina, 1 per cent free moisture).
2d.-coat mixed with 0.25 gal. and 3d.-coat with 1 gal. extra turpentine.

No. 309 -- French ochre, (13 to 24 per cent ferric oxide, 48 per cent silica, 20 per cent alumina, loss on ignition 10 per cent)

No. 310 -- Chrome yellow, light
Primer mixed with 1.39 gal., 2d-coat with 2 gal., 3d.-coat with 3.14 gal. extra turpentine.

No. 311 -- Chrome yellow, orange.

No. 312 -- Prussian blue.

No. 313 -- Lampblack
Primer mixed with 2.78 gal., 2d-coat with 7.13 gal., 3d-coat with 4.74 gal. extra turpentine.

No. 314 -- Graphite
Graphite was considered a leaf-shaped pigment like aluminum and was accordingly mixed in the proportion of 1.9 lbs. per gal. of linseed oil containing drier.

No. 315 -- Red lead.

No. 316 -- Litharge
The litharge was stirred into the liquids without first grinding with oil in the paint mill.

The 400 Series -- Inert Pigments and Mixtures of Aluminum with Granular Pigments

The 400 series was in two parts, the first of which consisted of single-pigment linseed oil paints made with inert (transparent) pigments mixed in the same proportions by volume as Series 200 and white lead paint No. X02.

No. 404 -- Asbestine
No. 405 -- Silica
No. 406 -- Barytes
No. 407 -- Blanc fixe
No. 408 -- China clay
No. 409 -- English chalk

The second part of series 400 consisted of aluminum, a leaf-shaped pigment, and granular pigments in linseed oil (No. 416 in Bakelite vehicle) made by mixing equal volumes of aluminum paint No. 114 (or No. 108) and granular pigment paints as follows:

No. 410 -- Aluminum and white lead, No. 114 and No. 202.
No. 411 -- Aluminum and red lead, No. 114 and No. 315.
No. 412 -- Aluminum, white lead, zinc oxide, asbestine, No. 114 and No. 213.
No. 413 -- Aluminum and zinc oxide, No. 114 and No. 207.
No. 414 -- Aluminum and iron oxide, No. 114 and No. 304.
No. 415 -- Aluminum and asbestine, No. 114 and No. 404.
No. 416 -- Aluminum and white lead in Bakelite vehicle, No. 108 and No. 503.

The 500 Series -- Vehicles with and without Granular Pigments

The 500 series was designed to study the effect of different paint vehicles on moisture movement through paints and through coatings of the vehicles alone, without pigments. The vehicles were linseed oil, 33-gal. ester gum varnish (see No. 111), 75-gal. ester gum varnish (see No. 110), Bakelite varnish (see No. 105), and Bakelite paint oil (see No. X03). The pigments were basic carbonate white lead, iron oxide (see No. 304), and asbestine. The proportions by volume of pigments and non-volatile part of the vehicle were always the same as in series 200 and in white lead paint No. X02 but the proportions of thinner in the paints made with varnish vehicles were, of course, higher in order to make the paints brushable. The two ester gum varnishes already contained sufficient thinner to attain that end. The Bakelite paint oil, however, contained only 11 per cent volatile by weight, which was sufficient for white lead paint but for iron oxide paint additions of turpentine were required in amounts of 2.3 gal. for primer, 2.13 gal. for second-coat, and 2.6 gal. for third-coat paint, and for asbestine paint, 1.3 gal. for primer, 1.17 gal. for second-coat and 0.94 gal. for third-coat paint.

No. 502 -- White lead in linseed oil.
No. 503 -- White lead in Bakelite paint oil.
No. 504 -- White lead in 75-gal. ester gum varnish.
No. 505 -- White lead in 33-gal. ester gum varnish.
No. 506 -- Iron oxide in Bakelite paint oil.
No. 507 -- Iron oxide in 75-gal. ester gum varnish.
No. 508 -- Iron oxide in 33-gal. ester gum varnish.
No. 509 -- Asbestine in Bakelite paint oil.
No. 510 -- Asbestine in 75-gal. ester gum varnish.
No. 511 -- Asbestine in 33-gal. ester gum varnish.
No. 512 -- Bakelite paint oil.
No. 513 -- Bakelite varnish (see No. 105).
No. 514 -- 75-gal. ester gum varnish.
No. 515 -- 33-gal. ester gum varnish.
No. 516 -- Linseed oil containing paint drier.

The 600 Series -- Pigment Concentration

The 600 series was designed to reveal the effect of variation in the ratio of pigment to drying oil on the effectiveness against moisture movement. Three paints were used, white lead in linseed oil, white lead in Bakelite paint oil, and white paint No. 214 (titanox B, zinc oxide, asbestine). The concentration of pigment is expressed in terms of pigment volume, which is the percentage of pigment by volume in the non-volatile part of the paint (pigment plus drying oil). For purposes of calculation it is assumed that the drying oil does not change in volume during drying and hardening of the paint coating.

The 600 series differs from all other series in that the second- and third-coat paints on group B, instead of being white lead paint, were paints of the same pigment composition as the priming-coat paint and mixed always in the proportions by volume given for white lead paint No. X02 in Table 2. For group C the second- and third-coat paints were identical with the primers both in composition of pigment and in proportions of pigments and liquids.

Basic carbonate white lead in linseed oil:

No. 602 -- Pigment volume 24.6 per cent.
No. 604 -- Pigment volume 29.0 per cent.
No. 605 -- Pigment volume 33.0 per cent.
No. 606 -- Pigment volume 38.7 per cent.
No. 607 -- Pigment volume 43.0 per cent.
No. 608 -- Pigment volume 47.7 per cent.

Titanox B, zinc oxide, asbestine in linseed oil:

No. 609 -- Pigment volume 29.0 per cent.
No. 610 -- Pigment volume 33.0 per cent.
No. 611 -- Pigment volume 38.7 per cent.
No. 612 -- Pigment volume 43.0 per cent.
No. 613 -- Pigment volume 47.7 per cent.

Basic carbonate white lead in Bakelite paint oil:

No. 603 -- Pigment volume 24.6 per cent.
No. 614 -- Pigment volume 29.0 per cent.
No. 615 -- Pigment volume 38.7 per cent.
No. 616 -- Pigment volume 47.7 per cent.

The 700 Series -- Spray Application

Mill-priming of lumber is usually done by spray application followed by forced drying at moderately high temperature. It is also customary to add more thinner to aluminum paint when it is sprayed. The 700 series was designed to determine whether these factors affect the resistance of the coating to moisture movement. Primers for groups A, B, and C and second- and third-coat paints for group C were applied by the tool indicated in the following list but second- and third-coat paints for group B were always applied by brush.

No. 702 -- White lead linseed oil paint, brushed.
No. 704 -- White lead linseed oil paint, sprayed.
No. 705 -- White paint No. 213, sprayed.
No. 706 -- White paint No. 214, sprayed.
No. 707 -- Aluminum paint No. 104, sprayed.
No. 708 -- Aluminum paint No. 108, sprayed.
No. 709 -- Aluminum paint No. 108 thinned with 0.25 gal. of mineral spirits, sprayed.
No. 710 -- No. 709 force dried at 160° F. (71 ° C.) for 1 hour.
No. 711 -- Aluminum paint No. 110, sprayed.
No. 712 -- Aluminum paint No. 110 thinned with 0.25 gal. of mineral spirits, sprayed.
No. 713 -- No. 712 force dried at 160° F. (71° C.) for 1 hour.
No. 714 -- Aluminum paint No. 112, sprayed.
No. 715 -- Aluminum paint No. 112 thinned with 0.25 gal. of turpentine, sprayed.
No. 716 -- No. 715 force dried at 160° F. (71° C.) for 1 hour.

Spreading Rates for Painting

Record was kept of the spreading rates at which paint was applied. In brush application this was done by weighing the paint bucket and brush before and after application to determine the amount of paint applied to the known surface area of the wood specimens. The weight of the paint per gallon was either computed from its formula or determined directly. In spray application the specimen was weighed immediately before and after application. Loss of volatile from the paint is negligible in brush application but is appreciable in spray application, tending to make the calculated spreading rate in square feet per gallon somewhat greater than the actual spreading rate when the spray gun is used.

The average spreading rate on corresponding specimens of the four species of wood is recorded in Table 3 for the priming-coat paints and for second- and third-coat paints of group C. For group B the second- and third-coat paints, except on certain specimens of the 600 series, were white lead paint mixed as stated in Table 1; the average spreading rate at which this paint was applied on all specimens was 690 square feet per gallon for the second-coat and 674 for the third-coat paint. For group B in the 600 series the spreading rates in square feet per gallon were 686 for second-coat and 791 for third-coat white lead linseed oil paint, 780 for second- and 906 for third-coat titanox-zinc-asbestine paint, and 544 for second- and 932 for third-coat white lead Bakelite oil paint.

White lead paint X02 for painted control specimens, (Table 2), was applied at 453, 740, and 659 square feet per gallon respectively for primer, second, and third coat; white lead Bakelite oil paint X03 was applied at 338, 721, and 632 square feet per gallon.

RESULTS

The measurements of effectiveness of the different coatings within each series are closely comparable because they were made on matched specimens of wood. The ratings reported are the averages of the four ratings obtained on each of the four species of wood. The grouping of the paints within each series was designed to bring together the kinds of paint between which closest comparisons are desired. Comparison of a paint tested in one series with a paint tested in another series is somewhat less reliable but the degree of uncertainty on that score can be gauged by the results with the two painted controls that were included in all series, painted respectively with white lead linseed oil paint and with white lead Bakelite oil paint. The results with these painted controls before they were exposed to the weather appear in Table 4.

Table 3. -- Spreading rates at which the paints were applied.

Reference No.	Description of the primer and of the second- and third-coat paints for group C	Spreading rate, sq. ft. per gal.		
		Groups A,B,C	Group C	
		Primer	2d.-coat	3d.-coat
	Series 100 -- Aluminum paints			
104	Paste aluminum, varnish A	400	580	710
105	Paste aluminum, Bakelite varnish	400	668	812
106	2 lb. dry aluminum, varnish A	348	530	608
107	1 lb. dry aluminum, varnish A	352	608	760
108	2 lb. dry aluminum, Bakelite	378	637	622
109	1 lb. dry aluminum, Bakelite	370	665	629
110	Aluminum in 75-gal. varnish	370	665	567
111	Aluminum in 33-gal. varnish	339	522	571
112	Aluminum in synthetic oil	409	536	572
113	Aluminum in shellac	338	531	514
114	Aluminum in linseed oil	374	639	789
115	Aluminum in bodied oil	361	467	577
116	Aluminum in lacquer	311	528	467
	Series 200 -- White linseed oil paints			
202	Basic carbonate white lead	453	735	625
204	Basic sulfate white lead	413	744	845
205	Leaded zinc oxide	392	836	745
206	Sulfate white lead and zinc oxide	377	682	775
207	Zinc oxide, lead-free	404	644	767
208	Timonox	408	761	865
209	Titanium oxide	403	796	878
210	Titanox B	425	737	823
211	Zinc sulfide	370	667	748
212	Lithopone	406	793	855
213	White lead, zinc oxide, asbestine	434	723	863
214	Titanox, zinc oxide, asbestine	451	747	895
215	Lithopone, zinc oxide, inerts	409	628	698
216	White lead,zinc oxide,high inerts	475	812	812
	Series 300 -- Colored linseed oil paints			
304	Iron oxide red	480	750	835
305	Spanish oxide	492	845	767
306	Venetian red, 40% iron oxide	513	730	790
307	Venetian red, 9% iron oxide	457	670	684
308	Yellow oxide	463	575	789

Table 3. (Continued)

Reference No.	Description of the primer and of the second- and third-coat paints for group C	Spreading rate, sq. ft. per gal.		
		Groups A, B, C	Group C	
		Primer	2d.-coat	3d.-coat
	<u>Series 300 -- Colored linseed oil paints (continued)</u>			
309	Yellow ochre	521	769	830
310	Chrome yellow, light	431	576	858
311	Chrome yellow, orange	473	825	713
312	Prussian blue	460	782	815
313	Lampblack	335	523	404
314	Graphite	404	745	650
315	Red lead	482	793	1090
316	Litharge	317	503	557
	<u>Series 400 -- Inert pigments in oil</u>			
404	Asbestine	506	750	630
405	Silica	406	495	552
406	Barytes	474	848	690
407	Blanc fixe	452	930	834
408	China clay	485	970	681
409	English chalk	433	730	786
	<u>Series 400 -- Aluminum and granular pigments</u>			
410	Aluminum and white lead	406	865	766
411	Aluminum and red lead	422	815	1050
412	Aluminum, and lead-zinc-asbestine	430	705	975
413	Aluminum and zinc oxide	456	737	820
414	Aluminum and iron oxide	420	665	686
415	Aluminum and asbestine	426	648	727
416	Aluminum, white lead, Bakelite	440	490	677
	<u>Series 500 -- Vehicles</u>			
502	White lead in linseed oil	453	778	655
503	White lead in Bakelite oil	338	721	682
504	White lead in 75-gal. varnish	482	505	638
505	White lead in 33-gal. varnish	478	469	577
506	Iron oxide in Bakelite oil	616	655	683
507	Iron oxide in 75-gal. varnish	454	549	759
508	Iron oxide in 33-gal. varnish	487	556	982

Table 3. (Continued)

Reference No.	Description of the primer and of the second- and third-coat paints for group C	Spreading rate, sq. ft. per gal.		
		Groups A,B,C	Group C	
		Primer	2d.-coat	3d.-coat
	Series 500 -- Vehicles (Continued)			
509	Asbestine in Bakelite oil	420	524	565
510	Asbestine in 75-gal. varnish	539	484	685
511	Asbestine in 33-gal. varnish	506	580	570
512	Bakelite paint oil	478	581	1020
513	Bakelite varnish	422	505	690
514	75-gal. ester gum varnish	427	526	731
515	33-gal. ester gum varnish	398	561	732
516	Linseed oil and paint drier	412	591	600
	Series 600 -- Pigment concentration			
	White lead in linseed oil:			
602	Pigment volume 24.6 per cent	453	662	662
604	Pigment volume 29.0 per cent	421	639	732
605	Pigment volume 33.0 per cent	424	652	771
606	Pigment volume 38.7 per cent	419	740	880
607	Pigment volume 43.0 per cent	418	754	875
608	Pigment volume 47.7 per cent	406	643	819
	Titanox-zinc-asbestine, linseed oil:			
609	Pigment volume 29.0 per cent	421	700	875
610	Pigment volume 33.0 per cent	442	825	1020
611	Pigment volume 38.7 per cent	470	700	889
612	Pigment volume 43.0 per cent	453	885	873
613	Pigment volume 47.7 per cent	456	791	---*
	White lead in Bakelite paint oil:			
603	Pigment volume 24.6 per cent	338	721	682
614	Pigment volume 29.0 per cent	379	495	---*
615	Pigment volume 38.7 per cent	426	591	837
616	Pigment volume 47.7 per cent	418	616	1000
	Series 700 -- Spray application			
702	White lead in linseed oil, brushed	453	740	674
704	White lead in linseed oil, sprayed	564	693	606
705	White paint No. 213, sprayed	434	667	695
706	White paint No. 214, sprayed	413	668	562
707	Aluminum paint No. 104, sprayed	617	854	856
708	Aluminum paint No. 108, sprayed	494	664	735
709	No. 108 thinned, sprayed	464	609	729
710	No. 108, thinned, sprayed, force dried	518	605	810

*Data lost through an accident.

Table 3. (Continued)

Reference No.	Description of the primer and of the second- and third-coat paints for group C	Spreading rate, sq. ft. per gal.		
		Groups A,B,C	Group C	
		Primer	2d.-coat	3d.-coat
	Series 700 -- Spray application (Cont.)			
711	Aluminum paint No. 110, sprayed	497	671	564
712	No. 110, thinned, sprayed	535	716	771
713	No. 110, thinned, sprayed, force dried	466	753	686
714	Aluminum paint No. 112, sprayed	533	654	671
715	No. 112, thinned, sprayed	527	849	655
716	No. 112, thinned, sprayed, force dried	460	808	708

Table 4. -- Effectiveness against moisture movement of the painted control specimens before exposure to the weather.

Reference No.	EFFECTIVENESS RATING						
	Group A	Group B, 2d. and 3d. coats white lead			Group C, 2d. and 3d. coat similar to primer		
	Primer only	Primer only	2 coats	3 coats	Primer only	2 coats	3 coats
White lead linseed oil paint							
102	27	27	63	72	23	62	73
202	21	18	61	68	19	63	73
302	21	10	63	71	13	56	69
402	24	17	57	68	16	56	67
502	18	15	53	70	19	61	75
602	19	17	52	68	20	55	66
702	16	13	53	73	13	47	72
White lead Bakelite oil paint							
103	72	69	82	84	66	86	92
203	63	64	78	79	68	86	89
303	60	55	80	80	58	84	86
403	61	60	78	80	61	84	88
503	62	57	75	81	65	86	91
603	64	64	85	89	66	84	87
703	61	61	77	83	60	84	88

Table 5 presents the results with all of the primers and paints that were tested, listed by series. Detailed discussion of the results will not be attempted at this time because it is desired to confine attention to certain general tendencies.

Table 5. -- Effectiveness against moisture movement of primers alone before and after exposure to the weather, of 2-coat paint jobs, and of 3-coat paint jobs before and after exposure to the weather.

Reference No.	Description of the primer and of the second- and third-coat paints for Group C	EFFECTIVENESS RATING: Group A, primer only, exposed to weather for 0 wks.	Group A, 6 wks.	Group A, 14 wks.	Group A, 26 wks.	Group B, 2d. and 3d. coats white lead (a): Primer only	Group B: 2 coats	Group B: 3 coats exposed 0 wks.	Group B: 3 coats exposed 26 wks.	Group C, 2d. and 3d. coats similar to primer: Primer only	Group C: 2 coats	Group C: 3 coats exposed 0 wks.	Group C: 3 coats exposed 26 wks.
	Series 100 -- Aluminum paints												
104	Paste aluminum, varnish A	70	64	62		70	83	85	88	71	87	92	94
105	Paste in Bakelite varnish	77	72	72		79	65	90	91	75	92	94	95
106	2 lb. dry alum., varnish A	45	41	43		37	84	88	89	47	92	94	95
107	1 lb. dry alum., varnish A	18	12	16		12	71	80	84	18	79	89	91
108	2 lb. dry alum., Bakelite	42	33	34		39	86	91	91	34	88	95	96
109	1 lb. dry alum., Bakelite	20	11	16		17	73	84	86	12	77	90	93
110	Aluminum in 75-gal. varnish	12	5	12		8	62	86	88	6	61	90	93
111	Aluminum in 33-gal. varnish	24	17	21		20	83	91	92	16	90	98	97
112	Aluminum in synthetic oil	16	9	16		14	72	86	86	9	81	93	95
113	Aluminum in shellac	18	5	11		21	71	87	86	11	78	92	90
114	Aluminum in linseed oil	12	7	15		15	64	82	86	15	57	77	85
115	Aluminum in bodied oil	30	24	31		24	75	84	87	24	84	89	92
116	Aluminum in lacquer	9	2	6		11	71	86	88	10	31	43	55
	Series 200 -- White linseed oil paints												
202	Basic carbonate white lead	21	16	20		18	61	68	78	19	63	73	79
204	Basic sulfate white lead	14	9	15		12	56	69	79	15	49	69	78
205	35% leaded zinc oxide	26	24	27		27	64	72	81	29	63	72	80
206	Sulfate lead-zinc oxide	30	32	34		32	65	72	81	32	70	75	81
207	Zinc oxide	34	35	39		40	67	73	83	36	68	75	82
208	Timonox	23	15	22		17	60	68	81	21	63	68	74
209	Titanium oxide	20	7	16		20	61	68	78	23	60	63	66

Table 5. (Continued)

Reference No.	Description of the primer and of the second- and third-coat paints for Group C	EFFECTIVENESS RATING: Group A, primer only, exposed to weather for 0 wks.	6 wks.	14 wks.	26 wks.	Group B, 2d. and 3d. coats white lead (a): Primer only	2 coats	3 coats exposed 0 wks.	3 coats exposed 26 wks.	Group C, 2d. and 3d. coats similar to primer: Primer only	2 coats	3 coats exposed 0 wks.	3 coats exposed 26 wks.
	Series 200 -- White linseed oil paints (Cont.)												
210	Titanox	27	17	20		20	59	68	76	22	60	64	68
211	Zinc sulfide	21	16	14		17	60	68	76	21	61	65	69
212	Lithopone	20	1	11		19	58	67	77	20	51	55	55
213	Lead, zinc, asbestine	24	16	20		32	67	72	82	33	71	74	82
214	Titanox, zinc, asbestine	20	15	19		21	62	69	81	24	65	70	79
215	Lithopone, zinc, inerts	28	22	22		30	65	70	79	32	73	75	82
216	Lead, zinc, high inerts	26	20	21		25	64	70	79	27	67	73	80
	Series 300 -- Colored linseed oil paints												
304	Iron oxide red	24	23	32		21	63	70	77	23	53	56	63
305	Spanish oxide	12	7	20		11	61	69	76	12	34	53	55
306	Venetian red, 40% Fe_2O_3	7	5	19		5	60	69	76	7	25	45	55
307	Venetian red, 9% Fe_2O_3	5	-3	14		6	63	72	77	6	55	62	65
308	Yellow oxide	24	21	29		21	62	68	75	24	55	63	66
309	Yellow ochre	15	16	28		10	61	70	76	14	39	52	58
310	Chrome yellow, light	29	30	38		25	65	69	75	26	49	56	71
311	Chrome yellow, orange	17	20	30		11	61	69	79	18	47	62	73
312	Prussian blue	14	16	25		10	60	69	76	17	46	58	65
313	Lampblack	19	19	27		22	67	71	77	27	38	58	60
314	Graphite	4	0	15		4	69	75	80	10	58	64	67
315	Red lead	19	22	28		10	66	72	82	19	56	67	78
316	Litharge	-2	-8	12		-9	60	83	89	1	12	60	70

Table 5. (Continued)

Reference No.	Description of the primer and of the second- and third-coat paints for Group C	EFFECTIVENESS RATING: Group A, primer only, exposed to weather for 0 wks.	6 wks.	14 wks.	26 wks.	Group B, 2d. and 3d. coats white lead (a): Primer only	2 coats	3 coats exposed 0 wks.	3 coats exposed 26 wks.	Group C, 2d. and 3d. coats similar to primer: Primer only	2 coats	3 coats exposed 0 wks.	3 coats exposed 26 wks.
	Series 400 -- Inert pigments in oil												
404	Asbestine	15	15	26		9	59	68	77	7	37	55	59
405	Silica	8	4	16		1	61	71	79	14	46	69	70
406	Barytes	16	12	20		9	57	68	76	5	53	60	64
407	Blanc fixe	23	13	21		16	55	60	78	14	47	60	63
408	China clay	13	14	25		6	60	68	77	7	34	55	59
409	English chalk	12	11	19		8	57	68	76	6	44	59	64
	Series 400 -- Aluminum and granular pigments												
410	Aluminum and white lead	8	11	21		4	60	73	80	9	58	72	74
411	Aluminum and red lead	12	4	16		3	60	75	83	6	65	75	83
412	Aluminum and lead, zinc	15	11	20		5	62	75	83	1	65	78	81
413	Aluminum and zinc oxide	25	28	33		13	67	75	83	12	63	77	81
414	Aluminum and iron oxide	15	9	18		4	58	74	80	8	61	73	76
415	Aluminum and asbestine	16	12	22		7	61	72	79	8	53	67	67
416	Aluminum, lead, Bakelite	36	34	33		33	77	80	85	40	88	90	89
	Series 500 -- Vehicles												
502	White lead in linseed oil	18	8	16		15	53	70	77	19	61	75	77
503	White lead in Bakelite oil	62	60	62		57	75	81	84	65	86	91	91
504	White lead, 75-gal. varnish	8	0	6		7	48	67	75	3	62	83	84
505	White lead, 33-gal. varnish	22	10	11		23	57	70	77	23	85	91	91
506	Iron oxide, Bakelite oil	3	-9	5		3	42	63	71	8	64	81	79

Table 5. (Continued)

Reference No.	Description of the primer and of the second- and third-coat paints for Group C	EFFECTIVENESS RATING: Group A, primer only, exposed to weather for 0 wks.	6 wks.	14 wks.	26 wks.	Group B, 2d. and 3d. coats white lead (a): Primer only	2 coats	3 coats exposed 0 wks.	3 coats exposed 26 wks.	Group C, 2d. and 3d. coats similar to primer: Primer only	2 coats	3 coats exposed 0 wks.	3 coats exposed 26 wks.
	Series 500 -- Vehicles (Continued)												
507	Iron oxide, 75-gal. varnish	33	28	36		34	61	70	77	39	75	82	79
508	Iron oxide, 33-gal. varnish	28	19	25		30	58	69	76	33	82	88	84
509	Asbestine, Bakelite oil	21	22	28		25	63	74	80	30	60	78	75
510	Asbestine, 75-gal. varnish	0	-7	6		5	50	65	74	14	50	70	65
511	Asbestine, 33-gal. varnish	20	6	12		18	55	67	75	30	66	83	76
512	Bakelite paint oil	0	-8	4		0	35	62	70	12	47	66	63
513	Bakelite varnish	0	-8	6		2	40	62	71	12	49	73	69
514	75-gal. ester gum varnish	0	-11	5		0	38	62	72	5	14	35	32
515	33-gal. ester gum varnish	0	-10	4		0	41	64	73	12	37	65	55
516	Linseed oil and paint drier	3	-11	4		0	36	63	72	3	5	21	21
	Series 600 -- Pigment concentration												
	White lead in linseed oil:												
602	Pigment volume 24.6%	19	23	15		17	52	68	77	20	55	66	76
604	Pigment volume 29.0%	16	21	15		14	54	68	77	18	51	62	73
605	Pigment volume 33.0%	21	30	19		18	53	68	77	24	53	63	73
606	Pigment volume 38.7%	26	34	21		21	55	69	77	25	55	63	75
607	Pigment volume 43.0%	25	28	17		22	55	71	78	26	56	64	75
608	Pigment volume 47.7%	27	29	18		23	59	71	79	26	60	67	76
	Titanox, zinc, asbestine, linseed oil:												
609	Pigment volume 29.0%	30	42	31		27	55	69	78	26	57	53	75
610	Pigment volume 33.0%	28	40	31		25	53	68	78	25	56	65	73

Table 5. (Continued)

Reference No.	Description of the primer and of the second- and third-coat paints for Group C	EFFECTIVENESS RATING: Group A, primer only, exposed to weather for 0 wks.	7 wks.	14 wks.	26 wks.	Group B, 2d. and 3d. coats white lead (a): Primer only	2 coats	3 coats exposed 0 wks.	3 coats exposed 26 wks.	Group C, 2d. and 3d. coats similar to primer: Primer only	2 coats	3 coats exposed 0 wks.	3 coats exposed 26 wks.
	Titanox, zinc, asbestine, linseed oil (Cont.)												
611	Pigment volume 38.7%	34	41	27		30	57	69	78	30	57	67	76
612	Pigment volume 43.0%	33	37	24		30	56	68	78	30	57	66	76
613	Pigment volume 47.7%	29	27	18		28	55	70	79	23	57	66	76
	White lead in Bakelite paint oil:												
603	Pigment volume 24.6%	64	69	60		64	85	89	93	66	84	87	90
614	Pigment volume 29.0%	58	62	49		57	82	88	92	60	82	88	91
615	Pigment volume 38.7%	39	39	26		37	81	88	93	40	83	87	91
616	Pigment volume 47.7%	41	39	22		38	80	89	93	45	84	85	90
Series 700 -- Spray application													
702	White lead paint, brushed	16	11	16		13	53	73	75	13	47	72	73
704	White lead paint, sprayed	4	2	8		1	48	75	75	3	44	68	71
705	Paint No. 213, sprayed	14	8	14		24	62	78	81	25	61	73	79
706	Paint No. 214, sprayed	14	12	17		15	56	76	80	23	58	72	74
707	Paint No. 104, sprayed	29	22	25		38	77	84	85	40	73	84	86
708	Paint No. 108, sprayed	4	-1	7		16	83	86	89	18	69	85	87
709	No. 108, thinned, sprayed	-4	-7	3		-4	69	87	88	7	72	86	89
710	No. 709 force dried	1	2	10		10	69	85	85	14	72	84	86
711	Paint No. 110, sprayed	-9	-7	3		8	62	85	87	4	51	83	84
712	No. 110, thinned, sprayed	-5	-6	3		3	54	85	83	1	19	67	68
713	No. 712 force dried	-3	-2	6		-2	56	84	84	-3	25	63	63
714	Paint No. 112, sprayed	3	-5	8		4	67	85	86	8	66	85	86
715	No. 112, thinned, sprayed	6	-4	4		22	59	86	86	-2	31	77	77
716	No. 715 force dried	4	-6	5		3	67	85	87	-6	38	65	69

(a) In the 600 series the 2d.- and 3d.-coat paints for group B contain the same ingredients as the primers but mixed always in the same proportions by volume as white lead paint No.XO2, Table 2

Effectiveness of Primers

It has been generally assumed that protection of the wood is attained in painting primarily by application of the priming-coat and that additional coats serve chiefly for appearance and durability. Back-priming depends entirely on that assumption as does mill-priming also insofar as it aims to protect lumber during shipment, storage, and erection. The results, however, show that nearly all of the primers tested were very low in effectiveness even when the same paint applied in three coats proved very effective indeed. Moreover there was no connection between the relative effectiveness of paints as primers alone and their relative effectiveness in two or three coats. For example, aluminum paints Nos. 110 and 112 proved much more effective in two- or in three-coat work than corresponding coatings of the common white paints, Nos. 202 and 213 to 216 inclusive, yet as primers alone the white paints were more effective than the aluminum paints. When, however, the two aluminum primers were covered with two coats of a white paint, such as white lead, the resulting coating was more effective than a three-coat job with the white paints alone. In other words these aluminum primers, although not particularly effective by themselves, contributed materially to high effectiveness in the completed paint job.

Four aluminum primers, Nos. 104, 105, 106, and 108, proved unusually effective even as priming-coats alone. Primers 106 and 108 owe their high effectiveness to the nature of the varnish vehicles because white lead primer No. 502, made with a very similar vehicle, proved even more effective than aluminum primer No. 108. But without any pigment, Nos. 512 and 513, or with iron oxide pigment, No. 506, this vehicle was very ineffective as a primer alone. In aluminum paints Nos. 104 and 105 the nature of the aluminum powder is also a potent factor in effectiveness, the fineness of the powder probably being the determining property. In another series of tests not included in this report it was found that the substitution of standard lining for standard varnish aluminum powder gave much the same comparative results as those found between aluminum paints Nos. 104 and 106.

It is evident that special primers can be made that will protect wood effectively when used as primers alone and will make good foundations for highly effective and durable coatings when covered by ordinary paints. Aluminum primer does not meet these dual requirements unless the grade of aluminum powder and the nature of the varnish vehicle are much more closely specified than is now customary. If the vehicle is wisely chosen, white primers of high effectiveness can also be obtained but it remains to be determined whether such primers will also have the property of retarding the flaking of paint coatings from conspicuous bands of summerwood that is the principal merit of good aluminum primers for wood (2, 3).

Theory of Wood Priming

In general each successive coat of paint applied to wood improves the effectiveness of the coating against moisture movement but the increments attributable to each of the successive coats are very unequal. One of the coats, usually the second, seems to achieve the major portion of the final effectiveness. For example, the effectiveness of white lead paint on specimens 202C attained 19 per cent for the primer, jumped to 63 per cent with the second coat, and then increased only to 73 per cent with the third coat. Aluminum paint No. 106 jumped from 47 to 92 per cent between the primer and second coat and then increased only to 94 per cent with the third coat. On the other hand with aluminum paint No. 104 the major portion of the effectiveness was attained with the primer, 71 per cent. Again, with litharge added to linseed oil without grinding, No. 316C, the effectiveness of the successive coats was 1, 12 and 60 per cent, respectively, the jump occurring between the last two coats. Oils and exterior varnishes without pigments, Nos. 512 to 516, built up effectiveness slowly and rarely attained great effectiveness even in three coats.

This characteristic jump in effectiveness at one point in the process of building a coating undoubtedly marks some distinct change in the physical nature of the coating that depends upon the characteristic behavior of paint on wood. Paint liquids penetrate wood measurably but pigments enter only as far as the cavities in those wood cells that have been cut off in planing the wood surface (4, 8). For that reason a paint primer is subject to a process of filtration as a result of which it becomes impoverished in liquid. The coating left when the drying oil hardens probably has a discontinuous matrix of linoxyn imperfectly filling the interstices between particles of pigment and is in consequence porous, but the pores are smaller and have less capillary capacity than the bare wood. If the primer is adequate it robs the second-coat paint of very little liquid and permits the second coat to harden with a continuous matrix, just as it would on glass or metal. Once a continuous matrix has been built up the coating ceases to be directly permeable to moisture-laden air and moisture passes through it only by absorption in the linoxyn, diffusion through the coating, and absorption by wood substance. The characteristic jump from low to high effectiveness against moisture movement therefore marks the transition from a porous to a nonporous coating.

Ordinarily primers are not to be regarded as protective coatings but rather as foundations for protective coatings. They are analogous to the wood filler used in hardwood finishing to provide a level, nonabsorptive surface for varnishing. For priming as for filling, oils or varnishes without pigments are much less satisfactory than mixtures rich

in pigment. Probably the function of the pigment is to form a finely porous layer capable of exerting capillary action in opposition to that of the wood so that absorption of liquid by the wood is restrained. The best primers are relatively rich in pigment; the results of the 600 series suggest that in linseed oil primers the pigment volume may well be as high as 30 to 40 per cent.

Aluminum powder, the particles of which are leaf-shaped rather than granular, is commonly supposed to float or "leaf" in paint liquids (although some paint technologists hold that no evidence of such leafing has yet been disclosed). Moreover aluminum primer is mixed with a much lower pigment volume than granular pigment primers. Aluminum primer therefore offers less capillary competition with wood than granular-pigment paints and may be expected to become more seriously impoverished in liquid. When a second coating again supplies it with liquid, however, the layer of aluminum powder apparently offers unusual resistance to the passage of moisture because of its peculiar structure. Those aluminum paints that are highly effective as primers alone are made with liquids that are easily restrained from penetrating into wood and with a fine grade of aluminum powder that is evidently capable of exerting more capillary competition than coarser powder. When such paints are applied on sheets of paper much less liquid penetrates through the paper to be seen on the reverse side than is true when ordinary aluminum paint is tested similarly.

Spray Application

The results of the 700 series indicate that spray application of either granular-pigment paints or aluminum paints yields somewhat less effective coatings than brush application. The discrepancy is most marked for the priming-coat and is least marked for the completed three-coat job. The Forest Products Laboratory has not studied spray application of paint as thoroughly as it has brush application and it is possible that more skillful operation of the spray gun would yield more effective coatings. Thinning aluminum paint for spray application seems to be distinctly undesirable. Forced drying at moderately high temperature did not alter the effectiveness markedly.

Conclusions

1. -- Paint primers, whether made with granular pigments or with aluminum powder, rarely afford wood much protection against moisture movement. As a rule the major portion of the protection offered by a paint coating is attained when the second coat of paint is applied.

2. -- As a primer alone, aluminum paint is usually less effective against moisture movement than a granular pigment paint made with the same vehicle, yet when a second and a third coat of ordinary paint are applied over the two primers the coating built upon the aluminum primer proves more effective than the one built upon the granular pigment primer.

3. -- Primers highly effective against moisture movement can be made with aluminum powder provided that a finely divided grade of powder is used in a special varnish vehicle.

4. -- Highly effective primers can also be made with granular pigments and varnish vehicles but it is not known whether such primers will retard flaking of aged coatings from summerwood as well as aluminum primer does.

5. -- An hypothesis of wood priming is advanced according to which a good primer is one that contains enough pigment in suitable form to exert a capillary competition with the wood for the paint vehicle in order to restrain penetration of liquid into the wood and to permit top-coats to harden with a continuous matrix that renders them non-porous with respect to moisture-laden air or liquid water.

6. -- Apparently spray-applied primers on wood are somewhat less effective against moisture movement than brush-applied primers. Thinning aluminum primer for spray application seems to be undesirable.

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